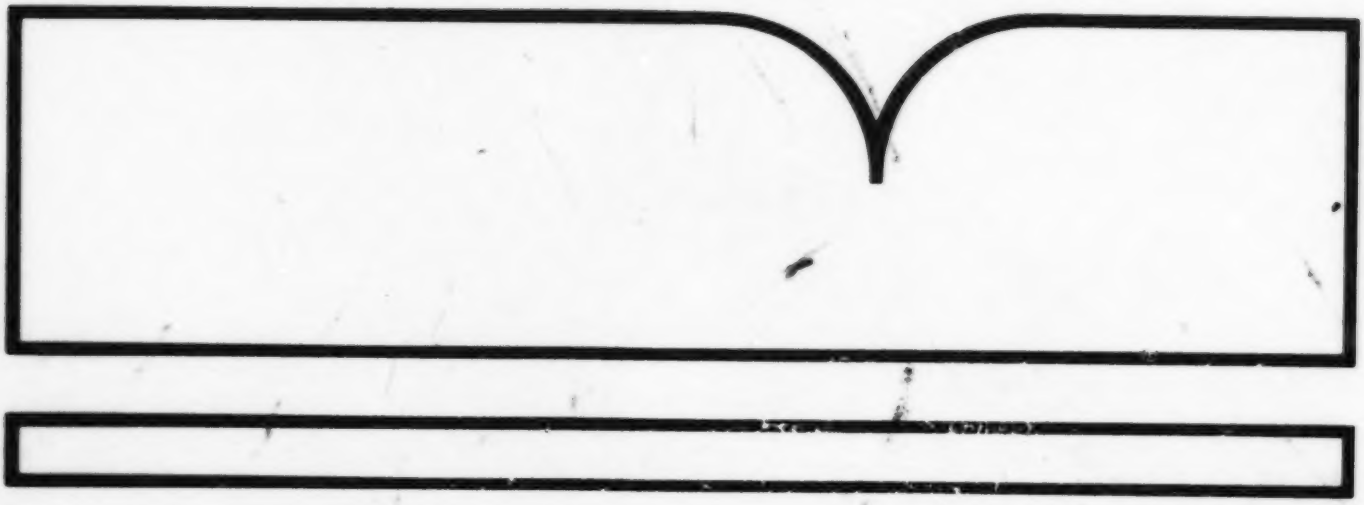
PB83-145227

Survival of Salmon Smolts in Sea Water after Exposure to Air-Supersaturated Water

(U.S.) Corvallis Environmental Research Lab., OR

17 Jul 78



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1. REPORT NO. EPA-600/J79-146	2. Journal Article
3. PB83-145227	
4. TITLE AND SUBTITLE: Survival of Salmon Smolts in Sea Water After Exposure to Air-supersaturated Water	5. REPORT DATE: 1979
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S): Alan V. Nebeker, Donald G. Stevens, Rocky J. Baker	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Environmental Research Laboratory, U.S. Environmental Protection Agency, Corvallis, Oregon 97333	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS: same	13. TYPE OF REPORT AND PERIOD COVERED: Journal Article
	14. SPONSORING AGENCY CODE: EPA/600/02

15. SUPPLEMENTARY NOTES

Published in The Progressive Fish-Culturist, Vol. 41, No.1, pp. 31-32, 1979.

16. ABSTRACT

Smolts of sockeye salmon (Oncorhynchus nerka) were held at 117, 115, 113, 110, 108, and 100% saturation in air-supersaturated fresh water at 12.5°C for 3 weeks. At 117% saturation 70% of the fish died, and at 115%, 5% died. Survivors were severely stressed and exhibited many signs of gas bubble disease. When the smolts were transferred to sea water and held for 10 days, no deaths occurred and they recovered rapidly.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

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NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

18. DISTRIBUTION STATEMENT: Release to public	19. SECURITY CLASS (This Report): Unclassified	21. NO. OF PAGES: 4
	20. SECURITY CLASS (This page): Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

EPA-600/J-79-146
JOURNAL ARTICLE

Survival of Salmon Smolts in Sea Water after Exposure to Air-supersaturated Water

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ABSTRACT: Smolts of sockeye salmon (*Oncorhynchus nerka*) were held at 117, 115, 113, 110, 108, and 100% saturation in air-supersaturated fresh water at 12.5°C for 3 weeks. At 117% saturation 70% of the fish died, and at 115%, 5% died. Survivors were severely stressed and exhibited many signs of gas bubble disease. When the smolts were transferred to sea water and held for 10 days, no deaths occurred and they recovered rapidly.

Several factors are known to alter the ability of juvenile salmon smolts to migrate successfully from fresh water to sea water (Hoar 1976). Fish that have not attained sufficient maturity have been shown to be incapable of adapting to sea water, and temperatures above 15°C during smolt growth may inhibit normal development of ATPase systems involved with osmoregulation, a function which has been shown to be necessary for smolt acclimation to sea water (Zaugg et al. 1972; Adams et al. 1975). Lorz and McPherson (1976) and Lorz et al. (in press) have shown that some chemicals, such as copper, may also affect smolt survival in sea water, but that many do not. Dawley et al. (1976) exposed juveniles of fall chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*Salmo gairdneri*) to air-supersaturated fresh water, and then sea water, and found that, in general, mature healthy smolts survived. Bouck et al. (1976) tested trout and salmon at 120% saturation and found that most survivors did not die when transferred to sea water.

The purpose of the present study was to expose smolts of sockeye salmon (*O. nerka*) to several concentrations of air-supersaturated fresh water, with subsequent introduction of sea water, to determine if there were residual effects due to supersaturation on the ability of smolts to adapt to sea water, and to determine the extent of fish recovery from severe gas bubble disease while in sea water.

Materials and Methods

Fish

Test fish were hatched and reared at the Western Fish Toxicology Station, Corvallis, Oregon, from adults collected from Bonneville Dam on the Columbia River. Mean fork length and weight of sockeye smolts during testing were 19.3 cm and 95.5 g. They were fed Oregon Moist Pellets while in fresh water, but nothing while in sea water. The fish were reared at 10-12°C and were checked for *Vibrio anguillarum* organisms during testing, using the methods of Stevens (1977). Behavior, signs of gas bubble disease, percentage survival, and extent of recovery in sea water were recorded.

Water

Fresh well water was injected with air under compression and then delivered at atmospheric pressure to the test tanks (Nebeker et al. 1976). Saturation was controlled by the amount of air injected. The test fresh water had the following characteristics: hardness, 31 mg/L and alkalinity, 23 mg/L (both as $CaCO_3$); pH, 7.1. Dissolved oxygen and other water chemistry analyses were conducted according to methods given in American Public Health Association et al. (1971). Saturation levels were measured with a Van Slyke gas analyzer, a Weiss saturometer, and by the Winkler method. To calculate total air supersaturation, we used the Weiss saturometer and the formula

$$\% \text{ saturation} = BP + \Delta P - VP/BP \times 100$$

where BP = barometric pressure, ΔP = saturometer reading, and VP = water vapor pressure. Natural sea water was obtained from DePoe Bay, Oregon, just before testing.

Testing

The supersaturated fresh water was introduced at the top of a partitioned ladder-like box (Figs. 1, 2) where it cascaded down over the partitions, serially stripping the water of excess gas. Six different concentrations of supersaturated water were delivered from the ladder to

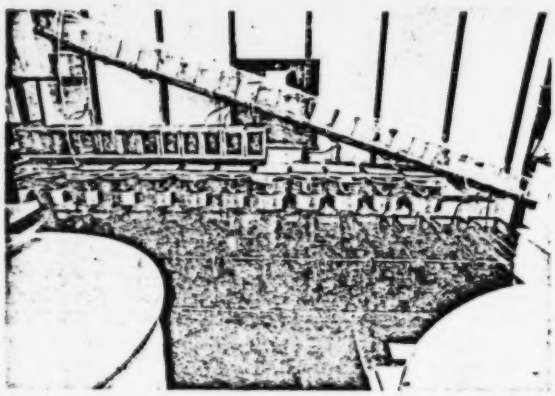

Fig. 1. Test facility, showing ladder-like box where supersaturated water is serially stripped of excess gas and delivered to test aquaria on bottom shelf.

the test aquaria, and duplicate aquaria were used for each concentration. Each held 100 L of water 28 cm deep with sufficient flow-through to maintain constant temperature and saturation. Fish were exposed to supersaturated water at concentrations of 117, 115, 113, 110, 108, and 100% air saturation at 12.5°C for 21 days. Ten fish were placed in each of the 12 aquaria. After the exposure to supersaturation they were gradually acclimated to un-supersaturated sea water by delivering sea water (14°C) to the aquaria; one-third sea water for 2 days, then two-thirds sea water for 1 day, and then undiluted (30‰) aerated sea water for 7 days.

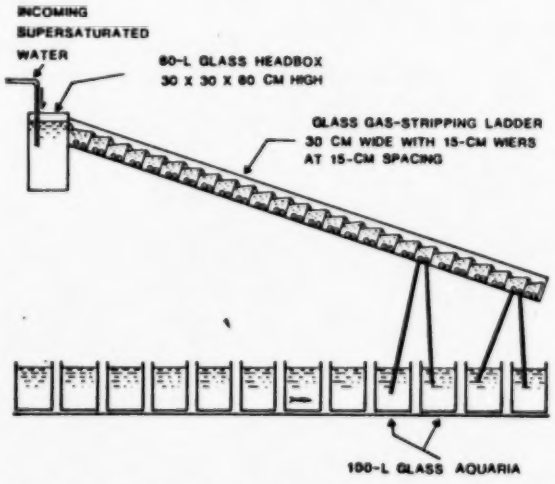

Fig. 2. Partitioned glass box, where supersaturated water is serially stripped of excess dissolved gases and different concentrations are delivered to 100-L aquaria.

Results and Discussion

Seventy percent of the sockeye smolts died at 117% saturation and 5% died at 115% saturation after 3 weeks exposure (Table 1). Fish surviving at 117 and 115% were convulsive and disoriented; they had exophthalmia and emphysema on the head, opercles, and fins. Emphysema occurred on the fins and tails of fish at 113% and on the tail of one fish at 110% saturation. One fish from 115% saturation had muscular emphysema, which caused a vacuolated, perforated "swiss cheese" appearance of the flesh. Stroud et al. (1975) have given detailed descriptions of gas bubble disease in salmonid fishes.

Table 1. Comparative survival of sockeye salmon smolts in sea water after 21 days exposure at 5 levels of air-supersaturated fresh water.

Mean percent saturation of fresh water	Percentage survival after 21 days exposure in fresh water[a]	Number of survivors transferred to sea water	Percentage survival after 10 days exposure in sea water
100	100	4	100
100	100	5	100
117	20	2[b]	100
117	40	4[b]	100
115	100	10[b]	100[c]
115	90	9[b]	100
113	100	10	100
113	100	10	100
110	100	10	100
110	100	10	100
108	100	10	100
108	100	10	100

[a] Ten fish exposed in each concentration.
[b] Fish were severely stressed and exhibiting many signs of gas bubble disease when transferred to sea water.
[c] One fish was swimming aimlessly.

Fish recovered rapidly from gas bubble disease after transfer to sea water and none died during the 10-day holding period. Emphysema disappeared, fish that had been floating and swimming erratically began to swim normally, and exophthalmia regressed. However, small scars remained on the opercles where lesions had occurred, and one fish exposed to 117% saturation still swam aimlessly, indicating probable brain damage from capillary blockage by bubbles in the blood stream. Vibriosis was not detected nor were *Vibrio* organisms cultured from the fish after holding in sea water. It is apparent from this study that our initial concern that fish, moving down the supersaturated Columbia River to the ocean, might survive the freshwater exposure but die in the ocean (where no effects could be observed) was unfounded; supersaturation did not cause any residual effects on smolt survival in sea water.

Acknowledgments

We thank James Nash for assistance with fish testing, Joel McCrady for assistance with water chemistry, and Robert Trippel and Richard Lewis for help with the saltwater exposure. We also thank the Oregon Department of Fish and Wildlife for adult salmon as our source of eggs for rearing test fish.

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Accepted 17 July 1978